Channel 6 problem

FEDERAL COMMUNICATIONS COMMISSION
Office of the Chief Engineer
Research Division

REPORT NO. R-6702

CALCULATIONS FOR EDUCATIONAL FM CHANNEL ASSIGNMENTS IN AREAS SERVED BY TV CHANNEL 6

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July 14, 1967

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SUMMARY

Interference over a considerable area will be caused to Channel 6 TV service if low-power transmitters operating on FM Channels 201-220 are located between the Grade A and Grade B contours of the Channel 6 TV station. Various factors must be considered when Educational FM stations are located within the Grade A contour, or beyond the Grade B contour, of a Channel 6 TV station. A design for determining these factors is described in this report.

INTRODUCTION

In this report TV receiver performance data from various sources will be summarized and analyzed, and calculations of the extent of interference to Channel 6 TV service by Noncommercial Edcuational FM stations will be described.

The following analysis is treated in two aspects. First, the natural limitations for Educational FM station operation beyond the Grade B contour of a Channel 6 TV station are considered. The second viewpoint deals with the limitations on such operation within the Grade A contour. In most cases it would not be practical to operate these FM stations in areas between the Grade A and Grade B contours unless there were no TV receivers within a considerable distance from the FM station.

TV RECEIVER PERFORMANCE

Information concerning selectivity characteristics of TV Receivers, obtained from various sources and for various conditions, is summarized in the Appendix. The most significant information, from a statistical viewpoint, was developed by the television receiver industry and reported by RTMA (FCC Docket No. 10315) in 1953. Although these measurements were made some 15 years ago, this information appears to be consistent with brief information recently obtained. It is possible that recently developed components will improve the performance of TV receivers. The efficient utilization of the frequency spectrum will soon require considerable improvement in the selectivity characteristics of TV receivers.

Calculations in this report are based on interference from a single source in the band from 88.1 to 91.9 Mc/s which degrades the picture reproduction of a Channel 6 TV signal as received by average installations. This degradation may be much greater where two or more FM channels are utilized in the same service area. Information is needed on intermodulation effects in existing and future models of TV receivers. It is the consensus of TV receiver experts that the upper adjacent channel interference characteristics for both monochrome and color TV receivers are similar.

In some communities it has been shown to be practical to apply traps or filters in TV receivers, effectively reducing the amount of interference caused by nearby FM stations to Channel 6 TV service.

INTERFERENCE BEYOND THE CHANNEL 6 GRADE B CONTOUR

Figure 1 is an overlay chart to be superimposed over Figure 17 of FCC Report No. R-6602 ("Development of VHF and UHF Propagation Curves for TV and FM Broadcasting"). It shows the minimum distance separating an Educational FM station with a given antenna height, effective radiated power (ERP), and FM channel number from the Grade B contour of a Channel 6 TV station. At this distance a picture of Grade 3 or better quality will be received at 50% of the receiving locations during 90% or more of the time. Under average conditions this service limitation occurs only near a point on the Grade B contour intersecting a line between the two stations. Interference will be increased at most of the locations nearer the FM station and no Channel 6 reception will be possible in its immediate vicinity without special antennas and filters on the TV receivers.

Figure 1 should be reproduced to scale on a transparent sheet for maximum usefulness. It is obvious that Figure 1 can also be used directly side by side with the other chart by projecting the desired coordinates to the required parameters. If a transparency is used place it over the F(50,50) graph (Figure 17, R-6602), with the coordinates projected to the desired parameters, thus allowing direct reading of the chart. The two graphs, Figure 1 of this report and Figure 17 of R-6602 may be used for the determination of the relative magnitudes of two remaining parameters when any two of the following parameters are known or are specified:

(1) Distance of the FM station beyond the Grade B contour of a Channel 6 TV station.

(2) Frequency or channel number of the FM station.

(3) Effective radiated power of the FM station.

(4) Antenna height of the FM station.

The horizontal axis at the bottom of each graph must always coincide to form a common line. The transparency is then moved horizontally until the FM ERP coincides with the antenna height indicated on Figure 17. The vertical coordinates of these two parameters will now coincide. The point of this intersection on the line for an FM channel shown on the transparency will be directly over the point indicating distance on Figure 17. This shows the required distance beyond the Grade B contour.

In Figure 2 an example is given of an FM station on Channel 213, with an antenna height of 400 feet and an ERP of 10 dBk. Using the technique outlined above, the transparency is shifted until the antenna height and ERP coincide; then the Channel 213 line on the overlay will intersect the interpolated mileage of Figure 17. This reading of 5.3 miles is the minimum separation allowable between the TV Grade B contour and the FM station. Similarly, for a Channel 201 FM station the allowable distance between the Grade B contour and the station will be 25 miles. Table I lists other possible combinations of values that can be obtained with the overlay in the same position.

The graph in Figure 1 was designed from the equation,

$$F_U = F_D - A + G_D - G_U - \lambda_D + \lambda_U - P_U + R \tag{1}$$

where F_U = Field strength, F(50,50), of the interfering FM station, in dB above 1 uV/m for 1 kW.

F_D = Field strength of the Channel 6 TV station at the Grade B contour for rated power = 47 dB above 1 uV/m.

A = Fading ratio = F(50,50) - F(50,90). This may be obtained from Figures 17 and 18 of R-6602. Assuming a normal distribution, A = F(50,10) - F(50,50) = 8.5 dB, when the distance is approximately 70 miles.

G_D = Gain of TV receiver antenna on Channel 6, relative to a $\lambda/2$ dipole.

G_U = Effective gain of the same TV receiver antenna in receiving the interfering FM signal, considering average difference in directions of arrival of the desired and undesired signals. It is assumed that $G_D - G_U = 6$ dB.

$-\lambda_D + \lambda_U$ = $-20 \log f_D + 20 \log f_U$, where f_D and f_U are the frequencies of the desired and undesired signals.

P_U = Effective radiated power of the FM station, dBk.

R = Interference ratio for average TV receivers as shown in Table II. At 47 dB desired signal field strength, as in Grade B service, this ratio is defined as the power difference (in dB) between the undesired and the desired signals (U - D) at the receiver antenna terminals, for average picture reproduction of Grade 3 or better.

INTERFERENCE BY FM STATIONS LOCATED WITHIN THE CHANNEL 6 SERVICE AREA

In the primary TV service area greater protection than that afforded beyond the Grade B contour is mandatory. We may assume that protection is satisfactory if the average receiver delivers a Grade 1 or 2 picture (interference barely perceptible) at practically all locations. For practical purposes pictures of "Grade 1-1/2" quality may always be considered as Excellent, and this may be taken as a "Grade 1" for the present purpose. Improving the picture quality from Grade 3 to "Grade 1-1/2" requires a reduction of the interfering signal by approximately 10 dB. For grade 2 about a 7 dB reduction is required. We may further assume that most TV receivers located within an interference area will require special technical modifications, or will suffer objectionable interference, and that "free-space" field strengths will, on the average, prevail at this range for the undesired signal.

To provide for the natural variation of field strength caused by terrain and path environment, data from the New York City UHF-TV Project (FCC Report No. R-6303) were examined. If 99% of the locations around the periphery of the interference zone is considered to be "practically all" of the locations to be protected, a factor equivalent to the difference between the median and 99% must be applied. The same procedure was followed in the case where 90% of the locations are to be protected. In the 99% case the New York measurements indicated a factor (L) of 30 dB for indoor antennas and 37 dB for rooftop antennas when receiving Channels 2 or 7. For the 90% figure the factor was 15 dB for indoor antennas. The 30 and 15 dB values are believed to be most appropriate for the present application since the pertinent areas of concern are those where field strengths permit the use of indoor antennas.

At most of the locations of interest in this analysis, the distances involved from the FM station are such that the average field strength will approximate that for "free space". The "free space" field strength of the FM station at a distance d (in miles) will be

$$F_U = 102.8 - 20 \log d + P_U \tag{2}$$

The field strength, in dB, of the TV station for interference-free service at this location must be at least

$$F_D = F_U + L - R' \tag{3}$$

where L is the location distribution factor, and R' is the interference ratio for the grade required (Table III). Substituting for F_U from (2),

$$F_D = 102.8 - 20 \log d + P_U + L - R' \tag{4}$$

In equation (4) the distance d, in miles, may be considered as the radius from the FM station of the area where interference may affect Channel 6 TV reception. This distance should be calculated from the center of the antenna array, and the effective radiated power, P_U, should be estimated by considering the vertical radiation pattern of the antenna. For example, at a distance of 0.20 mile (1056 feet) from an antenna radiation center 500 feet above ground, the actual horizontal distance from the base of the antenna tower is 0.17 mile (946 feet), and the depression angle is 26.4 degrees. These calculations apply to a receiver antenna 30 feet above ground.

If an Educational FM station is to be located within the Grade B or Grade A contour of a Channel 6 TV station, information must be obtained on the density of population in the areas described above, on the utilization of the service provided by Channel 6, and on the practicality of modifications of TV receiver installations within these areas for the reduction of interference which may be caused by the FM station. For average locations, examples may be considered where the limit of the interference area is at 0.20 mile from the radiation center of the FM antenna. At this 0.20 mile distance, pictures having Grade 2 or better quality at no less than 90% of the locations, may be considered tolerable. Destructive interference will be caused at most of the locations at distances closer than 0.20 mile. The curves in Figures 3, 4, 5 and 6 were calculated from equation (4), and indicate the channel and maximum mileage separations required for the protection of locations beyond 0.20 mile, for various effective radiated powers.

The limits over the FM educational band of the relation between the separation required for the FM station from the Channel 6 TV station, and the radius of the resulting interference area, are shown in Figures 7 (for FM Channel 201) and 8 (for FM Channel 220). For 10 watts ERP, at the Channel 6 Grade A contour, the radius of interference for Grade 2 picture quality, is 8.5 miles for FM Channel 201 and 0.75 mile for Channel 220. In the example for a radius of interference of 0.20 mile, under any conditions, the power of the FM station must be considerably less than 1 watt. For effective radiated powers greater than 1 kW, a Channel 220 FM station must be located at a maximum distance of about 6 miles from a Channel 6 TV station. This separation diminishes as the frequency is decreased in approaching Channel 201, and for the first few channels the FM station antenna must be located on the same tower with the Channel 6 TV station's antenna.

For higher effective radiated powers, minimum interference would be caused if the TV and FM station antennas both were at a common location. For this condition, the effective radiated power of the FM station must be less than

$$P_U \leq P_D + R' - K \qquad (5)$$

where K is a factor for equalization of incidental differences in the directivity of the two antennas. It is suggested that this should be K = 10 dB for average conditions. Correlation of the two signals is such that a location distribution factor will not be required.

In the above examples the interference ratios listed for Grade 2 pictures in Table III were applied.

CONCLUSIONS

In average conditions, any transmitter with an ERP more than 1 watt in the band from 88 to 92 Mc/s will cause serious interference in the area between the Grade A and Grade B contours of a Channel 6 TV station. Mounting of both Educational FM and Channel 6 TV antenna arrays on the same structure results in the most satisfactory performance. Various factors must be considered when Educational FM stations are located within the Grade A contour, or beyond the Grade B contour, of a Channel 6 TV station. A design for determining these factors is described in this report. In applying average parameters to any given receiver location where TV service is utilized, the ranges of variation in receiver and antenna performance, in signal strengths, and in cross-modulation effects with strong signals, must all be taken into consideration. The calculations shown in this report will be useful in estimating average interference effects for average conditions. At many of the locations where average TV reception will be degraded by FM station interference, it will be possible to reduce this interference by installing traps or filters, or by improving the receiver antenna system.

It should be noted that co-channel and adjacent channel (TV Channel 5) interference will be present at some locations and at some times within the Grade B contour of a Channel 6 TV station. This report considers only the interference which may be caused by transmitters in the band from 88 to 92 Mc/s, and other sources of interference are ignored.

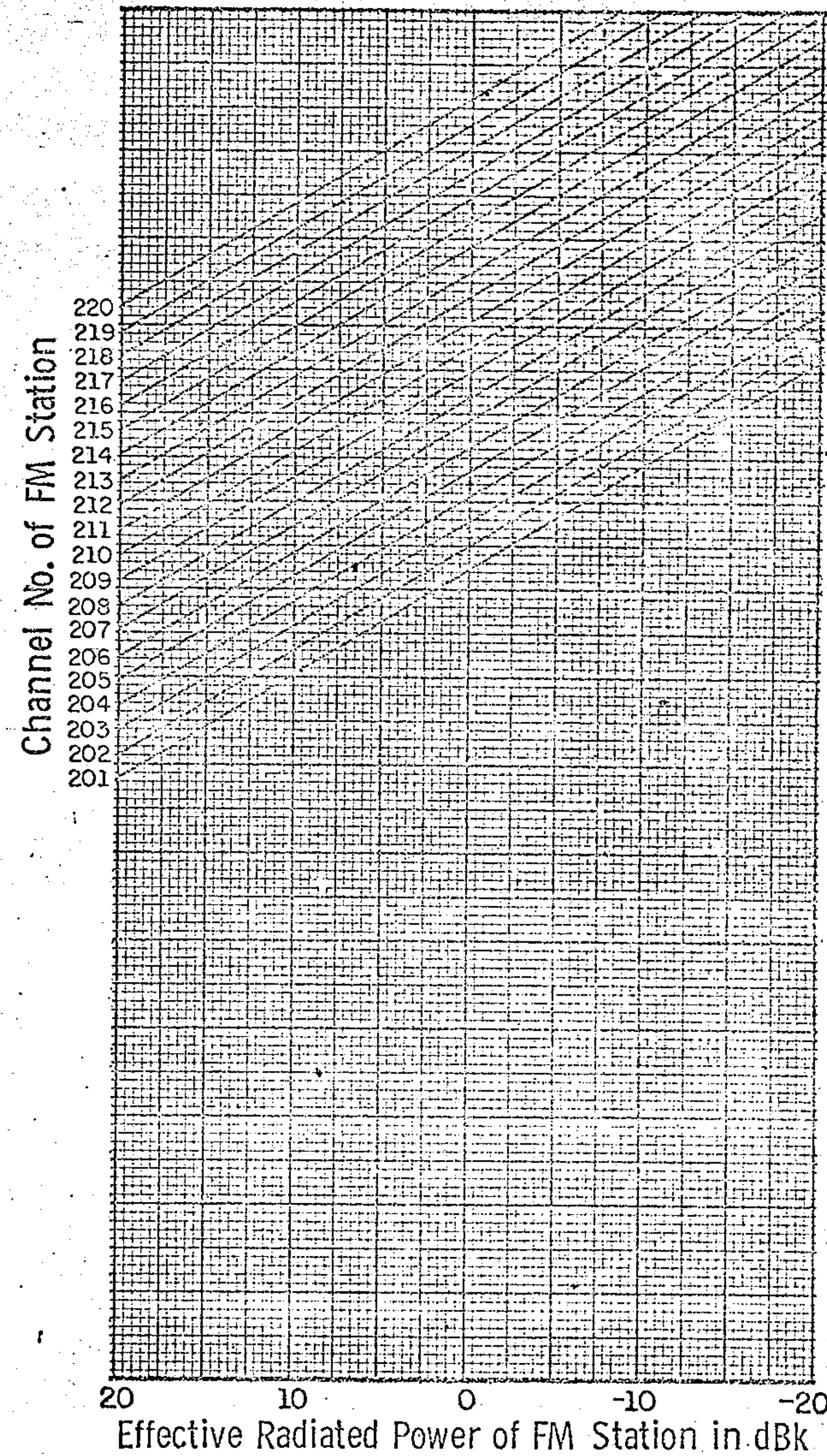

Channel No. of FM Station
220
219
218
217
216
215
214
213
212
211
210
209
208
207
206
205
204
203
202
201
20
10
0
-10
-20
Effective Radiated Power of FM Station in dBk

FIGURE 1

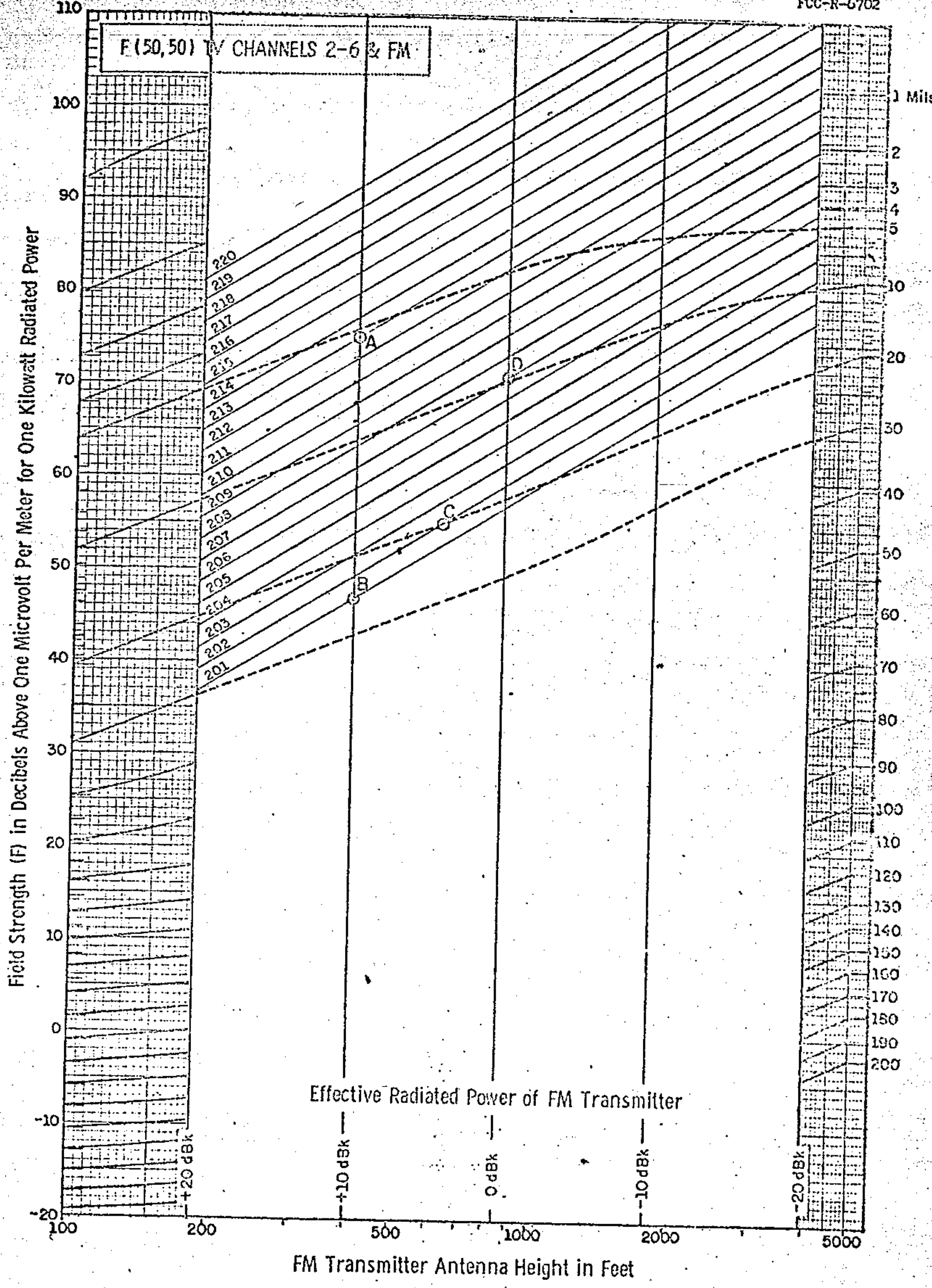
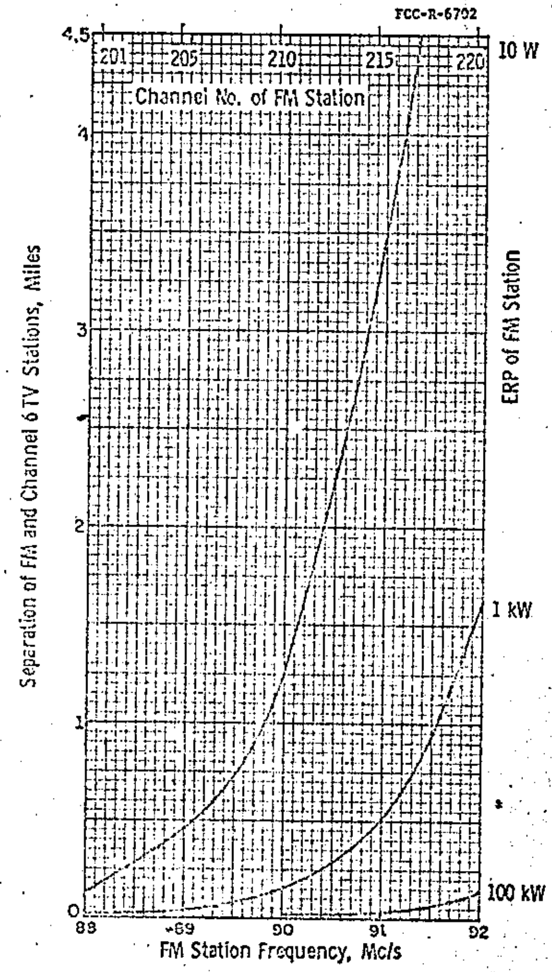

F(50,50) TV CHANNELS 2-6 & FM
Field Strength (F) in Decibels Above One Microvolt Per Meter for One Kilowatt Radiated Power
FM Transmitter Antenna Height in Feet
Effective Radiated Power of FM Transmitter
+20 dBk
+10 dBk
0 dBk
-10 dBk
-20 dBk
Mils
A
B
C
D
201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220
100 200 500 1000 2000 5000
110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
1 2 3 4 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200

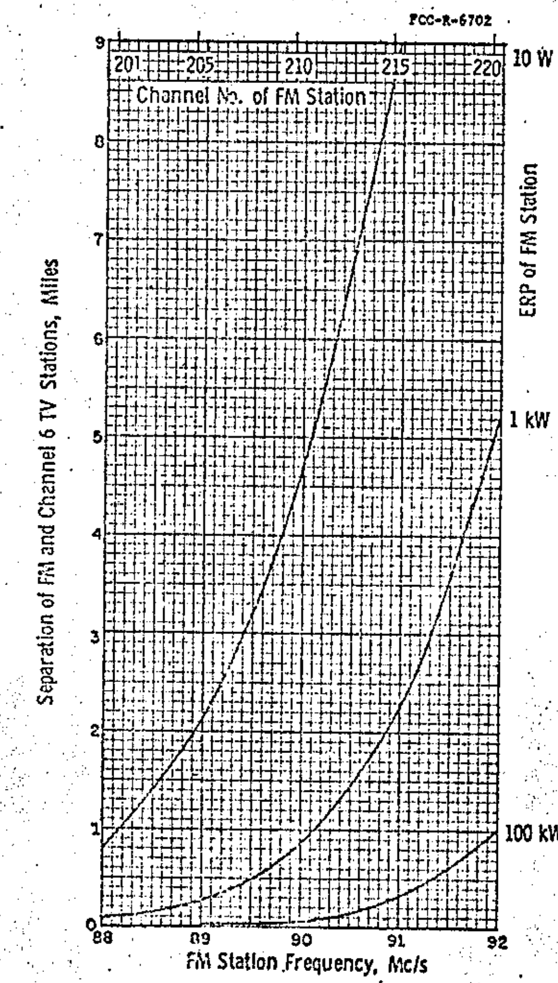
FIGURE 2



SEPARATION DISTANCES FOR VARIOUS FM CHANNELS

TV Channel 6, ERP 20 dBk, H_t 1000 ft.
1 % Interference at 0.2 miles radius. Grade 1 picture quality.

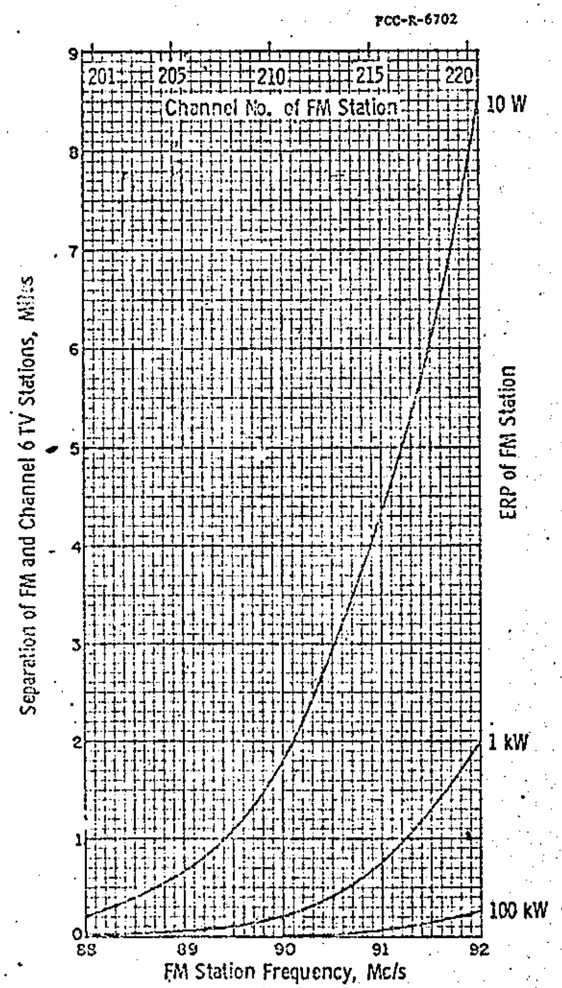
Figure 3



SEPARATION DISTANCES FOR VARIOUS FM CHANNELS

TV Channel 6, ERP 20 dBk, H_t 1000 ft.
10% Interference at 0.2 miles radius. Grade 1 picture quality.

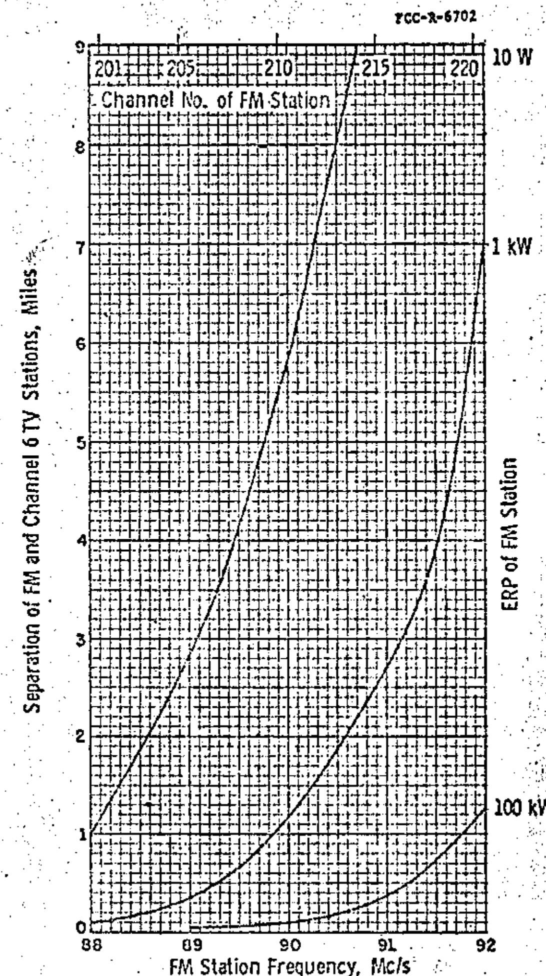
Figure 4



SEPARATION DISTANCES FOR VARIOUS FM CHANNELS

TV Channel6, ERP 20 dBk, H_t 1000 ft.
1% Interference at 0.2 miles radius. Grade 2 picture quality.

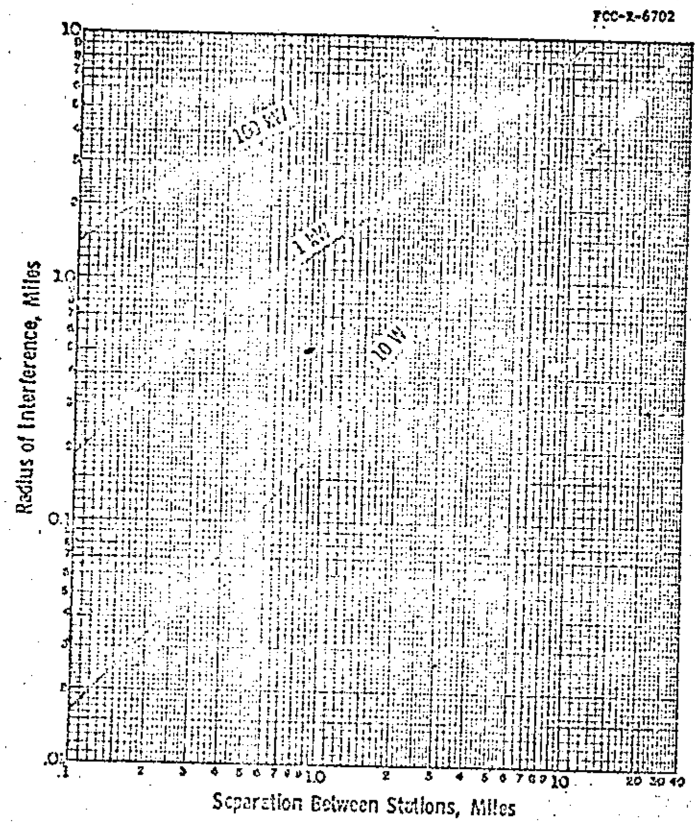
Figure 5



SEPARATION DISTANCES FOR VARIOUS FM CHANNELS

TV Channel6, ERP 20 dBk, H_t 1000 ft.
10% Interference at 0.2 miles radius. Grade 2 picture quality.

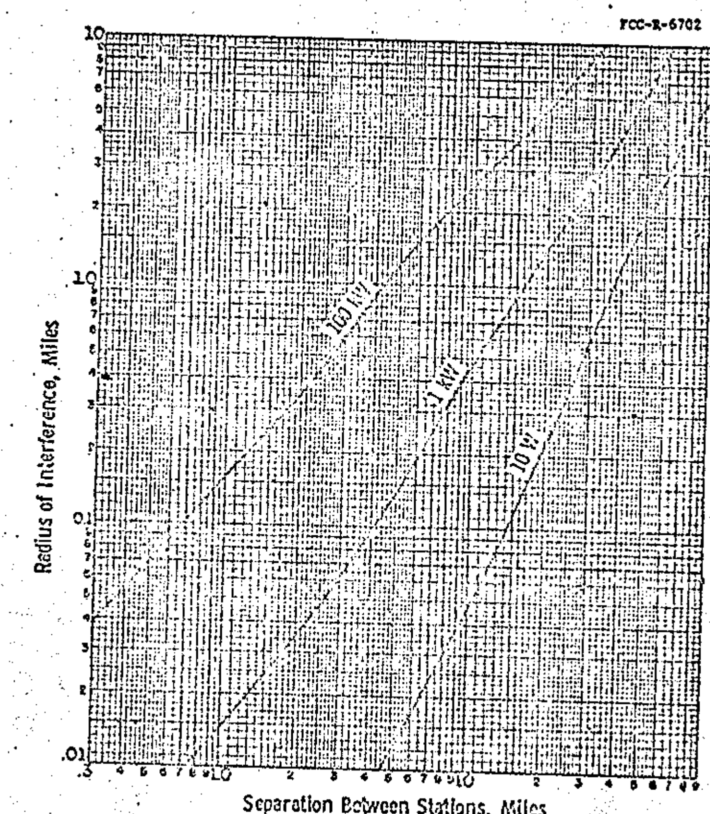
Figure 6



INTERFERENCE RADIUS VS. SEPARATION DISTANCES BETWEEN TV AND FM STATIONS

TV Channel 6, ERP 20 dbk, H_t 1000 ft.
FM Channel 201, H_t 500 ft.
10% Interference. Grade 2 picture quality.

Figure 7



INTERFERENCE RADIUS VS. SEPARATION DISTANCES BETWEEN TV AND FM STATIONS

TV Channel 6, ERP 20 dBk, H_t 1000 ft.
FM Channel 220, H_t 500 ft.
10% Interference. Grade 2 picture quality.

Figure 8

APPENDIX

TV RECEIVER ADJACENT-CHANNEL REJECTION CHARACTERISTICS

FCC Docket No. 10315 (Feb. 1953) contains the most extensive data in the Commission's record on TV receiver performance in rejecting adjacent-channel interference. An analysis of this data is summarized in this report in the form of a tabulation of the interference ratio versus frequency of the undesired carrier.

Adjustments of data were necessary to form a common basis of analysis. A Grade 1 picture was considered "excellent", but for the purpose of this report a practical estimate of Grade 1 would be Grade 1-1/2. Experience gained by TASO and by the Commission provided estimates of about 3 dB difference between Grade 1-1/2 and Grade 2, and about 7 dB difference between Grade 2 and Grade 3 pictures. Grade 3 pictures are considered to be passable, where interference degradation is not objectionable. The data in FCC Docket No. 10315 were for just perceptible interference levels visible close to the TV screen, and so the interference ratios were adjusted to a Grade 3 level of interference by adding 10 dB. Table 1A shows the interference ratios for various levels of picture degradation. For strong signal conditions in the Channel 6 primary service area, up to 20 miles from the TV station, the interference ratio was decreased by from 15 to 20 dB, depending on the frequency of the undesired signal, to provide for decreases in receiver selectivity in accordance with information contained in the Docket No. 10315 record. It was assumed that these conditions should apply for the Grades 1 and 2 ratios shown in Table 1A.

Figure 1A contains the results of an analysis of the data on the ability of TV receivers to reject adjacent-channel interference contained in Docket No. 14185. In order to make a comparison of all the rejection ratios, it was necessary to make adjustments depending on the conditions under which these ratios were measured.

The shaded area in Figure 1A represents data obtained by the Canadian Department of Transport (Interim Report; December 8, 1966) in investigations of FM interference to TV Channel 6. The values shown were considered to be Grade 3 for "weak" signals, and therefore were used as reported without adjustment. The upper and lower limits of the shaded area are for the 50% of receivers closest to the median value, among 15 typical monochrome receivers tested. These interference ratios agree reasonably well with those reported in Docket No. 10315, as represented by the dashed curves in Figure 1A.

Data submitted by the Engineering Staff of Storer Broadcasting Company were FM station interference levels from field tests conducted around WITI-TV Channel 6 in Milwaukee, Wisconsin. The tests were conducted near 3 FM stations in the service area of WITI-TV and the severity of interference was noted until no interference was observed. Four levels of interference were listed; severe, moderate, light, and none. The ratios of the FM field strength to the TV field strengths were calculated and adjusted to approximate Grade 3 picture levels as closely as possible. "Severe" interference was taken to be Grade 5 or 4 and 14 dB was subtracted from the rejection ratio for Grade 5, and 7 dB was subtracted for Grade 4. "Moderate" interference was taken to be Grade 3 and so no correction was needed. "Light" interference was taken to be Grade 2 and 7 dB was added to the rejection ratio. No interference was taken to be Grade 1-1/2, and 10 dB was added to the rejection ratio. These estimates were based on TASO data combined with information obtained from various sources.

The Association of Maximum Service Telecasters, Inc., reported on the results of a survey taken on several Channel 6 stations which have FM stations within an 80 mile radius of them. From the data reported, the curves from FCC Report No. R-6602 were used to estimate FM field strengths for the distances involved. Using the reported TV field strength, the ratios of FM to TV field strength were calculated. No correction was applied to these ratios since they probably represent average conditions.

Comments filed by the Engineering Department of Triangle Publications, Inc. (Radio and Television Division), and Kear and Kennedy, Consulting Engineers, contained laboratory measurements of 2 monochrome and 1 color TV receiver for adjacent-channel interference rejection with both strong and weak desired signals. The interfering signal was adjusted in small steps through an equivalent frequency spectrum of 80 to 95 Mc/s and the signal level noted where "just perceptible" interference occurred. It was noted that as much as 20 dB of variation occurred on the color receiver rejection ratio for small changes in frequency. This was the result of the generation of cross-modulation products and the maximum and minimum occurred near intervals of 15 kc/s. These effects of small frequency changes were not included in the values shown on the comparison graph and so the values can be subject to a variation of ± 5 dB from the actual values. To change these "just perceptible" levels to Grade 3, 10 dB was added to the rejection ratio. Kear and Kennedy made spot field tests of "just perceptible" interference to WFIL-TV Philadelphia, Channel 6 TV from FM stations. The values obtained differed from the laboratory tests by -18 to +14 dB for the color set and -13.5 to +9 dB for the monochrome set. These field tests are not shown on the comparison graph.

The comparison of the rejection ratios from all the data appears to be quite scattered but in general agreement to those used in this report. Much of the scattering comes from the assumptions made as to the testing conditions and to the relatively few numbers of receivers used.

TABLE 1A

AVERAGE INTERFERENCE REJECTION RATIOS

Frequency of Undesired Signal	Interference Ratios for Weak Signals, at the Grade B Contour (R = U - D) Grade 3 Pictures	Interference Ratios for Strong Signals (R' = U - D)* Grade 2 Pictures	Interference Ratios for Strong Signals (R' = U - D)* Grade 1 Pictures
88 MHz	11.7 dB	-10.3 dB	-13.3 dB
89 MHz	23.6 dB	0.4 dB	-2.6 dB
90 MHz	35.3 dB	10.8 dB	7.8 dB
91 MHz	47.2 dB	21.5 dB	18.5 dB
92 MHz	59.0 dB	32.0 dB	29.0 dB

* These values include "lambda factor" corrections.